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A DIGITAL AUDIO LINK TO THE CHANNEL ISLANDS IN THE UHF TELEVISION BAND:

Planning considerations

M.C.D. Maddocks, B.Sc. (Eng)., A.M.I.E.E., and A.P. Robinson, B.Sc., A.R.C.S.

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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Summary

A digital link at UHF has been proposed as a means of feeding radio programmes over the trans-horizon sea path to the Channel Islands. The theoretical performance of such a link and its compatibility with existing UHF transmissions is investigated. It is predicted that such a link will operate with a reliability in excess of 99.5% time (due to propagation phenomena) and that it will not cause interference to existing UK or French UHF television transmissions.

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M.E.B. Moffat

Head of Research Department

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Section Page

1. **Introduction** 1

2. **Planning Considerations** 1

3. **System Ruggedness** 2

   3.1 **Carrier-to-noise ratio** 2

   3.2 **Carrier-to-interference ratio** 3

4. **System Compatibility** 6

   4.1 **Co-channel interference to UK services** 6

   4.2 **Adjacent-channel interference to UK services** 7

   4.3 **Co-channel interference to French services** 8

5. **Conclusions and Recommendations** 10

6. **Acknowledgement** 11

7. **References** 11

Appendix 1 **Equations relating signal power out of an aerial to the field strength of the signal** 12

Appendix 2 **UHF propagation calculation** 12

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1. INTRODUCTION

The Band II VHF/FM transmitter at Rowridge is scheduled for re-engineering. To comply with the agreements reached at the 1984 ITU Regional Administrative Radio Conference on VHF Broadcasting the aerial radiation pattern will be modified to radiate a lower power towards France. The network radio feed to the Channel Islands is provided by a diversity arrangement whereby stereo signals are received from transmitters at both North Hessary Tor and Rowridge. The signal from North Hessary Tor is normally preferred but both are needed to ensure continuity of stereo service because of the occurrence of fading.

As a result of the change, the transmitter on the Channel Islands will effectively lose its Band II feed. An additional link is therefore required to replace it. A digital link has been proposed as a replacement and will be installed initially on an experimental basis. The proposed link uses one of the existing UHF high gain receiving aerials on Alderney; these were installed to provide the television feed to the Channel Islands. The aerials receive horizontally polarised signals from the transmitter at Stockland Hill and so the digital feed will also be transmitted horizontally polarised from there. Channel 30 is proposed for the link as the channel which would cause least interference to both United Kingdom and French transmissions (within the range of channels which are broadcast from Stockland Hill). It is proposed that the signal be radiated from the UHF station at Stockland Hill at a relatively low effective radiated power (e.r.p.) using a high gain aerial. This will minimise the level and potential areas of interference to French services. The location of the sites and the path of the proposed link are shown in Fig. 1.

It is proposed that the radio programmes be transmitted in digital form using a NICAM-3 baseband coding technique[1]. Using this technique a 2.048 Mbit/s NICAM-3 data stream carries 6 monophonic or 3 stereophonic channels. Two 2.048 Mbit/s data streams will be modulated onto separate carriers using a Tamed-FM (TFM)[2] modulation technique which results in a spectrum about 2 MHz wide. The two modulated carriers will be positioned within the chosen television channel.

The purpose of the Report is to describe the planning aspects of this link. Initially the general planning requirements of ruggedness of service and compatibility with existing services are outlined and then the specific link is considered in detail. Other Research Reports describe the establishment of interference protection requirements[3] and the results of a preliminary trial[4].

2. PLANNING CONSIDERATIONS

A new transmission system must be engineered such that it is rugged enough to provide the required service and is compatible with existing transmissions. The system in question will be affected by propagation conditions which can be described statistically. Therefore it is necessary to define an acceptable level of performance and plan the system to maintain the service for that percentage of time. In a similar way, compatibility with existing services can be examined statistically.

The ruggedness of a transmission system can be specified in terms of the signal quality which is achieved for a given percentage of the time. The signal quality is limited by the ratio of the level of wanted signal to the levels of noise and unwanted signals. The latter can be considered to include co-channel interference and adjacent-channel interference from other services and multipath propagation of the wanted signal. Multipath can be caused by anomalous atmospheric effects or scattering off objects. In all these cases the carrier-to-noise ratio (*C/N*) and carrier-to-interference ratio (*C/I*) can be found if the propagation statistics, the receiving aerial directional pattern and filtering in the receiver are known. The signal quality resulting from a particular *C/N* or *C/I* can then be determined from published results or by experiment.

To ensure compatibility of the new system with existing transmissions, it is necessary to consider all cases in which interference may be caused. Therefore the permissible levels of in-band and out-of-band signals must be found. The level of interference will depend on the radiated power of the proposed transmission, the radiation pattern of the transmitting aerial, the propagation conditions and the terrain profile. The required level will be dictated by the required protection ratio and the signal strength of the existing transmission.

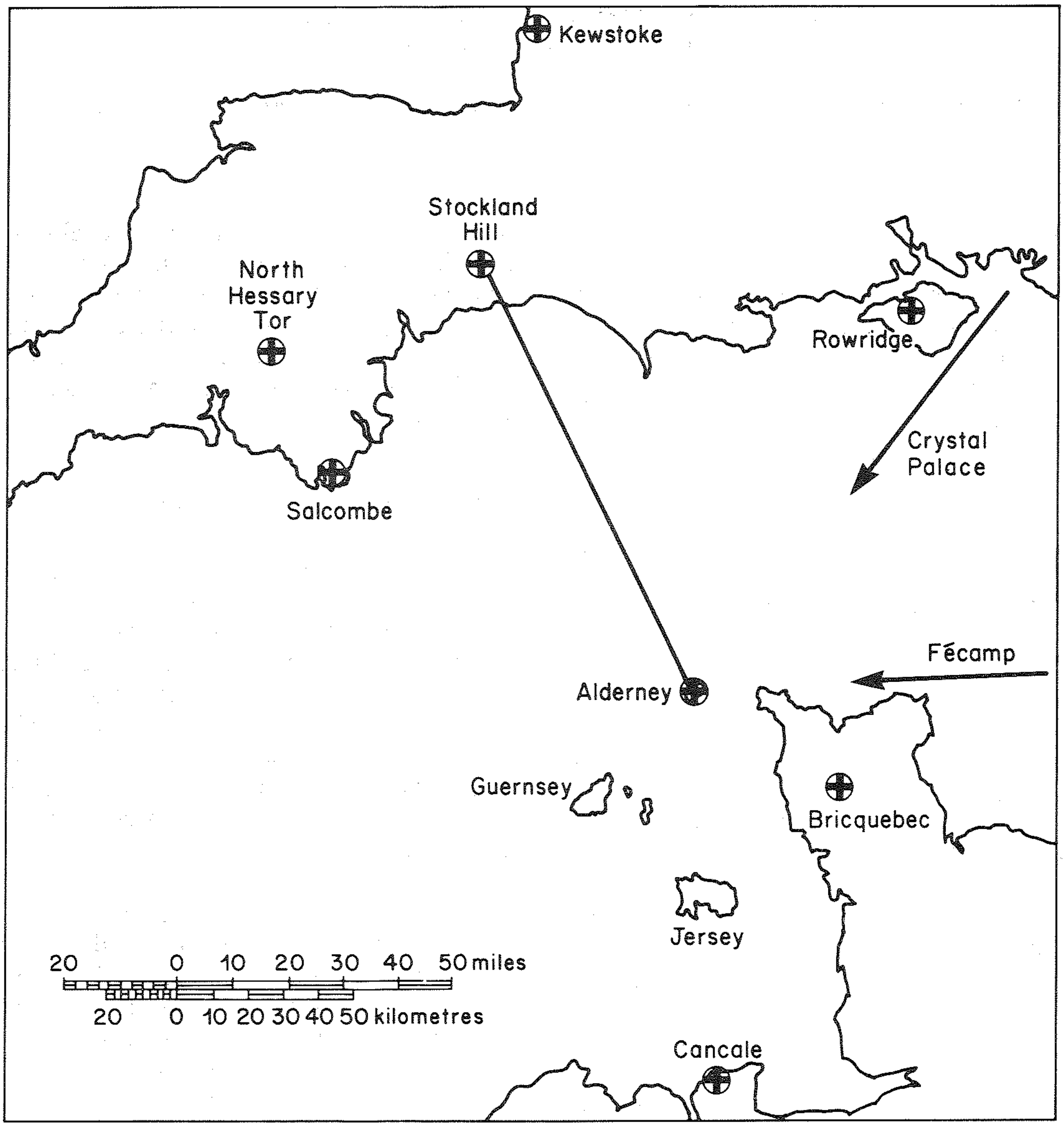

Fig. 1 - Geographical location of transmitting and receiving sites.

3. SYSTEM RUGGEDNESS

To allow the system to perform satisfactorily for the required percentage of time it is necessary to ensure that the link has an adequate *C/N* and *C/I*. Extensive propagation measurements were made when the UHF television service to the Channel Islands was installed[5,6] and so the field strength for a particular percentage of time can be predicted based on these measurements. This will allow the determination of the transmitter e.r.p. required to maintain the link for the desired percentage of time. For convenience the results which follow are presented in terms of the estimated performance for the chosen e.r.p.

3.1 Carrier-to-noise ratio

Alderney is beyond the radio horizon of Stockland Hill for all reasonable receiving aerial heights. Therefore propagation is often due to scattering mechanisms which give rise to deep fades. At other times, ducts are formed over the English Channel and the signal strength rises above the free-space value.

Some seasonal variation in propagation conditions can also be observed[5]. Fig. 2 shows the statistics of the field strength of the Stockland Hill transmission on Channel 26 recorded at two different receiving aerial heights[6]. The height of 94.8 m a.o.d.* is the approximate height of the log-periodic aerial array which will be used for this link.

A block diagram of the receiving installation is shown in Fig. 3. It is proposed that an existing UHF high-gain receiving aerial is used on Alderney. This aerial receives horizontally polarised signals from the

* above ordnance datum, which is mean sea level.

transmitter at Stockland Hill and so the link uses horizontally polarised signals. The receiving aerial consists of an array of twenty four log-periodic aerials[6]. The gain of the aerial is 21.1 dBd (dB with respect to a $\lambda/2$ dipole) and the system noise figure, assuming a receiver noise figure of 4 dB, is 4.1 dB. The C/N achieved for various percentages of time can be predicted, see Table 1.

Table 1: Carrier and noise powers predicted for various percentages of time for reception on Alderney

	99.5%	99.9%
Field strength on Alderney from Stockland Hill exceeded for the given percentage of time for 250 W e.r.p.	21 dBμV/m	15 dBμV/m
Corresponding power into band-pass filter (see Fig. 3)*	-88 dBm	-94 dBm
Equivalent noise power, referred to the input of the band-pass filter, in a bandwidth of 2.048 MHz	-107 dBm	-107 dBm
Resulting C/N	19 dB	13 dB

* full analysis is given in Appendix 1

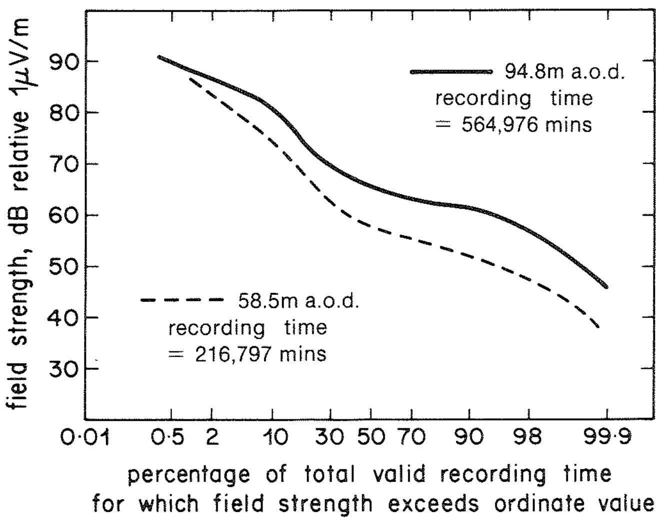

Fig. 2 - Field strength statistics of Stockland Hill transmission (Channel 26) received at Alderney.

Therefore a C/N of better than 19 dB should be achieved for 99.5% of time, and better than 13 dB for 99.9%. Tests on the equipment to be used show that a C/N of 15 dB is required to give adequate sound quality. From the measured field strength statistics this should be exceeded for 99.85% of time. However, this analysis takes no account of interference from other services using the channel.

3.2 Carrier-to-interference ratio

The proposed link uses a UHF television channel in between two of those at present used by the transmitter at Stockland Hill. This allows the existing aerial installation on Alderney to be used for the link. The result of this is that there will be both co-channel and adjacent-channel interference from existing services as well as the potential for multipath of the wanted signal from ships and aircraft in the English Channel. The effect on the bit-error ratio of single delay multipath has been investigated for a QPSK† modulation system[7]. The results show that an echo level of 25% to 30% is necessary to degrade the noise margin by 3 dB even in the worst case. However there is no statistical evidence of the incidence of such multipath effects and so it is not possible to draw any conclusion about the degradation that may result.

Predictions can be made for the case of television interference from existing propagation measurements. It may be assumed that the digital signals will be placed between the vision and sound carrier positions in the wanted channel and in that case adjacent-channel interference need not be considered further as negligible power will be radiated outside the notional television channel. Only the co-channel interference case need be considered. The carrier-to-interference ratio required will depend on the position of the wanted carrier within the channel, the vision information and, to a lesser extent, sound information being carried by the interfering signal.

An experiment was performed to find the optimum frequencies for the wanted digital signals in the presence of co-channel interference (CCI). In the

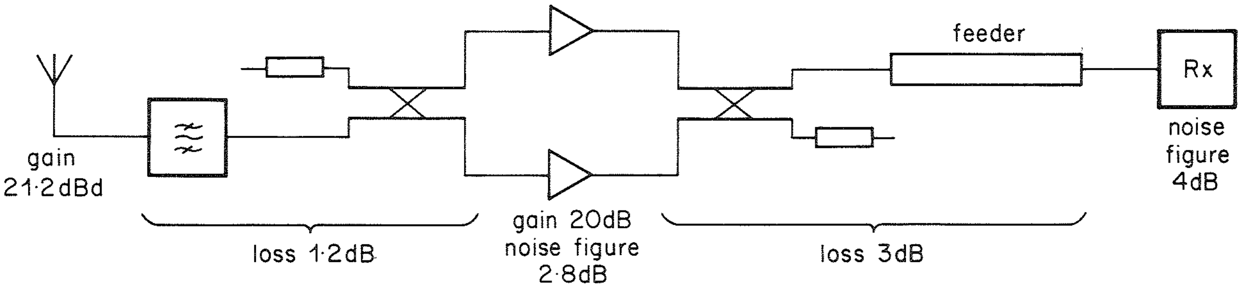

Fig. 3 - The Alderney receiving installation.

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† Quaternary Phase Shift Keying

experiment, see Fig. 4, the digital signal was placed at different positions in the television channel. Initially the picture material used for the CCI was chosen to be the EBU slide 'Trees' because it provides a typical spectrum (i.e., a spectrum where all frequencies are present in roughly even amounts). This was thought to allow the most appropriate appraisal of the optimum position of the digital signal. Because the sound modulation is FM and occupies a relatively narrow bandwidth the choice of sound material was thought to be relatively uncritical and so a tone was used.

TFM, with a bit rate of 2.048 Mbits/s, is proposed for the link because service equipment is available. This equipment was not available at the time of the tests and so an experimental 2.048 Mbits/s offset-QPSK (OQPSK) system was used. It was thought that the results with TFM would be similar and this was confirmed later by a brief experiment.

The digital signal was positioned at different offsets from the vision carrier and interference was added until a particular bit-error ratio (b.e.r.) was obtained. The carrier-to-interference ratio (*C/I*), the ratio of unmodulated OQPSK carrier power to peak synchronising pulse power, was then measured. The results given in Fig. 5 show a distinct minimum where both the vision and sound carriers lie outside the bandwidth of the OQPSK receiver, as would be expected. The effect of the colour-sub-carrier can be seen to be unexpectedly small.

It is proposed to place two, 2 MHz wide digital signals in the channel. From Fig. 5 the optimum frequencies for them can be found to be 2.4 MHz and 4.4 MHz above the position of the vision carrier. The effect of worst-case picture material on the bit-error ratio at each of these frequencies was then investigated independently. At 2.4 MHz above vision carrier, the worst-case picture material was found to be 'Ceefax in vision' slides. At 4.4 MHz above vision carrier the worst case video material was unsurprisingly found to be 100% colour bars. The carrier-to-interference ratios required to produce various bit-error ratios with these worst-case picture materials are given in Table 2. These results show that with low noise levels a carrier-to-interference ratio of -10 dB can result in a degradation in the performance of the link. In practice the link may be required to operate in both a poor carrier-to-noise and carrier-to-interference environment simultaneously. A carrier-to-interference ratio of 0 dB was chosen as a realistic figure that should be maintained to prevent degradation of link in the presence of noise.

Table 2: C/I required to produce various bit-error ratios with worst-case picture material

b.e.r.	frequency offset	
	2.4 MHz	4.4 MHz
10^{-5}	-10 dB	-13 dB
10^{-3}	-13 dB	-14.5 dB
10^{-2}	-17.5 dB	-15 dB

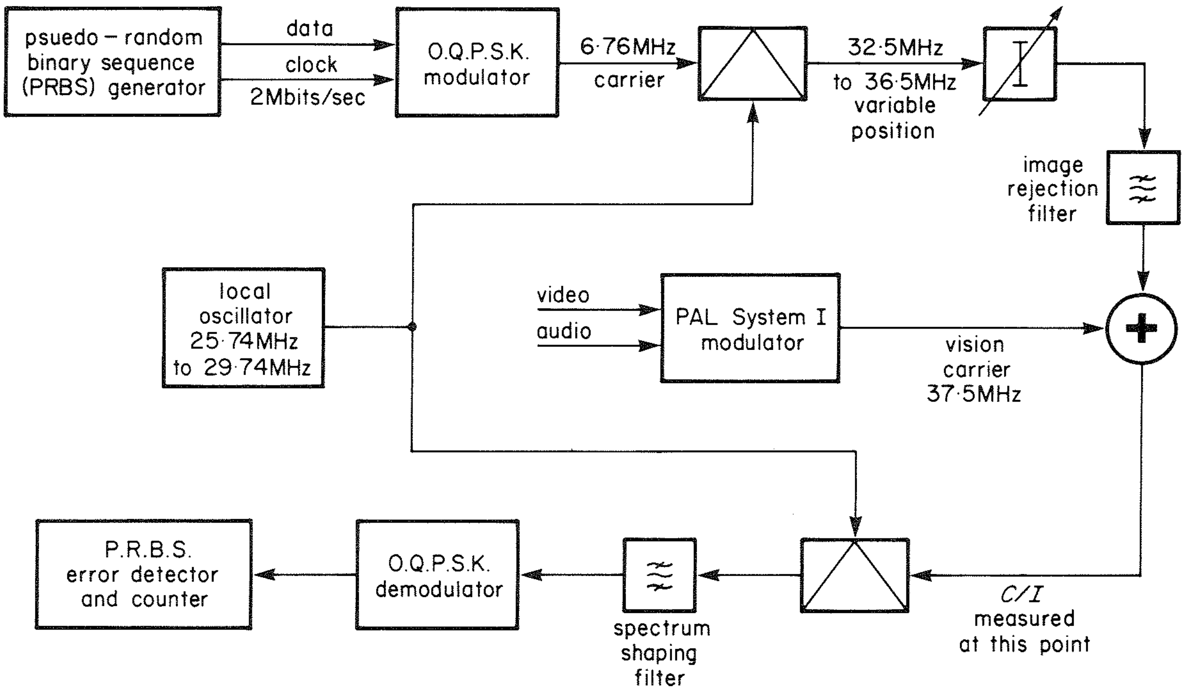
psuedo – random binary sequence (PRBS) generator
data
clock
2Mbits/sec
O.Q.P.S.K. modulator
6·76MHz carrier
32·5MHz to 36·5MHz variable position
image rejection filter
local oscillator 25·74MHz to 29·74MHz
video
audio
PAL System I modulator
vision carrier 37·5MHz
P.R.B.S. error detector and counter
O.Q.P.S.K. demodulator
spectrum shaping filter
C/I measured at this point

Fig. 4 - Experimental set-up to investigate the performance of the digital signal in the presence of co-channel television interference.

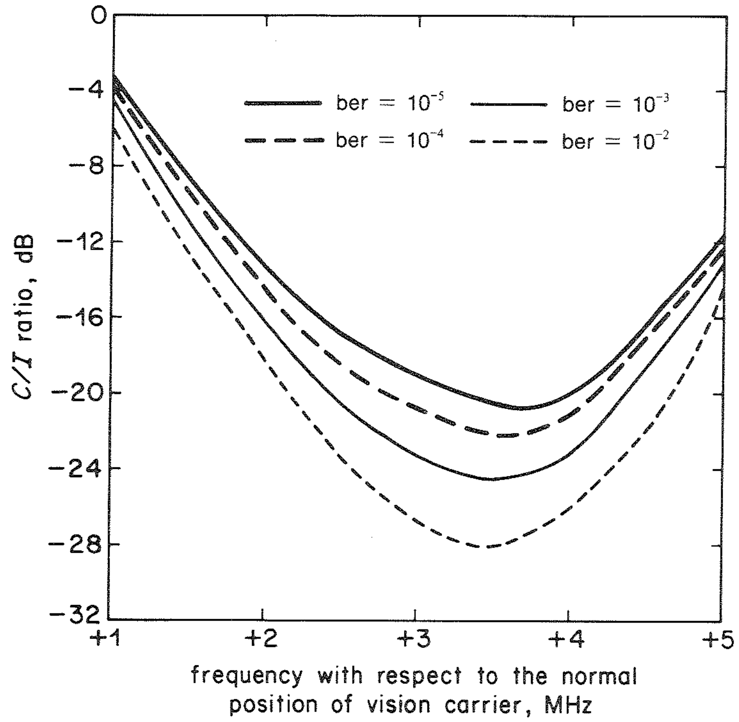

Fig. 5 - Carrier-to-interference ratio versus offset in frequency of the digital carrier from the normal vision carrier position.

A negative C/I indicates that the interfering signal power was larger than the wanted signal power.
Interfering video signal was EBU test slide "Trees".

The level of transmitted power at Stockland Hill required to protect the signal on Alderney to better than 0 dB carrier-to-interference ratio for 99.5% of the time can be estimated. An e.r.p. of 250 W per carrier has been assumed and statistics are derived for each source of interference. The calculations are based on the method and data presented in Ref. 8. This reference reports measurements and calculations used in the planning of the UHF television feed to the Channel Islands which uses the same path from Stockland Hill to Alderney.

The most suitable channel to use, from consideration of interference to and from existing services, is Channel 30. There are three potentially significant sources of signals which are co-channel to the proposed link; these are Crystal Palace, Fécamp and Cancale. The latter two stations have not yet been built although they were agreed internationally many years ago. The relative bearings of the stations are shown in Table 3.

Whilst in theory the receiving aerial exhibits considerable directivity, thus rejecting the interfering signals, there is, in practice, a loss of directivity as a result of scattering of the interfering signal off the sea surface and other obstructions in front of the aerial. Assessment of the level of co-channel interference is considered in detail in Section 6 of Ref. 8. The results should be independent of the receiving aerial, providing that it has enough directivity to reject signals from the direction of the interferers, as the loss of directivity is due to scattering off obstructions in the main beam of the aerial. This is true for the array of log-periodic aerials for which the theoretical discrimination (element factor plus array factor) is 50 dB or more for each of the three main sources of interference.

The interference calculations follow closely the method of Ref. 8, as follows. Let X represent the wanted signal strength, Y the interfering signal strength and Z the apparent aerial directivity in the presence of scattering, in dB. P denotes the wanted-to-interfering power ratio, C/I, at the array output. A bar indicates the median value. Then

$$\overline{P} = \overline{X} - \overline{Y} + \overline{Z}$$

Let σ_X, etc. be the respective standard deviations, and ρ_{XY}, etc., the cross-correlation coefficients. In the reference, a measured value of zero for ρ_{ZX} is given, for a signal representative of that from Crystal Palace, and ρ_{XY} and ρ_{YZ} are assumed to be 0.5 and zero, respectively. The same values will be assumed for the other two interferers. Then

$$\sigma_P^2 = \sigma_X^2 + \sigma_Y^2 + \sigma_Z^2 - 2\rho_{XY}\,\sigma_X\,\sigma_Y$$

The measurements in Ref. 6 give $\overline{X}$ = 38 dB μV/m (adjusted for 250 W e.r.p.), σ_X = 7 dB, and for Crystal Palace, $\overline{Z}$ = 37 dB and σ_Z = 4 dB. No measurements of aerial directivity are available for Cancale and Fécamp. As a pessimistic assumption, the values for Crystal Palace may be used. In practice, the directivity is likely to be better for Fécamp, because the scattering angle is larger, and better still for

Cancale, because the scattering angle is larger again, and some of the potential scattering objects are screened by the island of Alderney. An optimistic assumption would be that at such angles negligible scattering occurs and the full aerial directivity is achieved, i.e. $\overline{Z} = 50$ dB, $\sigma_Z = 0$ dB.

The parameters Y and σ_Y are extrapolated from the 1%-time and 5%-time field strengths given by the latest version of the computer prediction program described in Ref. 9. They are shown in Table 3.

Table 3: Details of interfering stations seen on Aldeney

Station	Bearing relative to main beam	Median field strength $\overline{Y}$, dBμV/m	Standard deviation σ_Y, dB
Crystal Palace	65°	32	17
Cancale	197°	59	4.5
Fécamp	115°	47	10.5

Applying the formulae for the protection ratio gives the results shown in Table 4.

Table 4: Estimated protection ratios for reception on Alderney

Station	Protection Ratios in dB				Percentage of time for which $\overline{P} > 0$ dB
	Median $\overline{P}$	Std. dev. σ_P	Percentiles		
			99.5th	99.9th	
Crystal Palace	43	15.5	3	-5	99.7
Cancale					
(pessimistic)	16	7.5	-3	-7	98.5
(optimistic)	29	6	13	10	99.99
Fécamp					
(pessimistic)	28	10	2	-3	99.7
(optimistic)	41	9.5	17	12	99.99

If interference from Crystal Palace is considered alone, the link should be maintained for 99.7% of the time. It should be noted that this is based on a conservative protection ratio requirement of 0 dB. To take noise into consideration as well, it seems reasonable to add the two outage times. This amounts to assuming that significant amounts of noise and interference do not occur together. Thus the link should operate for 99.55% of the time.

If the stations at Cancale and Fécamp are built, the outage time may increase. Table 4 shows that the result depends very much on the assumptions made about the aerial directivity. In particular it is thought that the directivity with respect to signals from Cancale would be significantly better than the pessimistic assumption for the reasons mentioned above. Thus it could reasonably be assumed that the protection ratio for each transmitter will exceed 0 dB for 99.9% of the time. Again, the outage times may be added together. This would be consistent with a partial correlation of the interfering field strengths, i.e. on some occasions more than one interferer may show a negative protection ratio whilst on other occasions the individual ratios may all be positive but the combined interference has the effect of a negative protection ratio. The link would then be maintained for 99.35% of the time.

4. SYSTEM COMPATIBILITY

To ensure compatibility between the new system and existing transmissions all cases where interference may be caused must be considered. In the case of this link, this splits into co-channel and adjacent-channel interference considerations to both UK and French transmissions. The link will be co-channel with two French transmitters: one (not yet built) at Cancale, which lies on the French coast south of the Channel Islands, and one at Bricquebec on the Cherbourg peninsula. If the system can be shown to be compatible in the more stringent co-channel case with such relatively close co-channel sites then adjacent-channel interference to French transmissions need not be considered further.

4.1 Co-channel interference to UK services

Co-channel interference may be caused to existing services in the United Kingdom which use Channel 30. The protection ratio which is required against digitally-modulated interference such as is proposed for this link is considered in a companion Report[3]. The worst-case result for the carrier frequencies that are proposed is 39 dB; this assumes that the interference occurs only for small percentages of time, in this case taken to be 1% of time.

In Band IV the limit of the service area is defined by a signal level of 64 dBμV/m. Therefore, to maintain a protection ratio of 39 dB, the interfering signal must have a field strength of less than 25 dBμV/m. The level of interfering signal from the link to other services can be predicted from CCIR Recommendation 370[10] and Report 239[11].

If the interference can be shown to be well below the limit, by the CCIR method, for a few representative examples compatibility can be established. This avoids the need to apply the more complex computer method and to consider many separate profiles.

The two transmitters closest to Stockland Hill which use Channel 30 are Salcombe and Kewstoke, see Fig. 1. The field strength for 10% and 1% of time at these sites can be estimated using CCIR Recommendation 370[10]. It is appropriate to consider reception in the vicinity of the transmitter because they are small relay stations. The field strengths can then be predicted using Refs. 10 and 11, these values are given in Table 5 for 250 W e.r.p.

Table 5: Predicted interference from Stockland Hill to UK services

Station	Bearing relative to main beam	Distance (km)	Field strength	
			10% time (dBμV/m)	1% time (dBμV/m)
Kewstoke	219°	64	31	36
Salcombe	65°	77	29	35

To minimise outgoing interference the transmitting aerial used by the proposed link is a high gain array. At angles greater than 40° from the main beam the e.r.p. will be at least 20 dB below the maximum. Taking this into account, the predicted field strength for 1% time at Kewstoke will be less than 16 dBμV/m and at Salcombe less than 15 dBμV/m. These values are both lower than the 25 dBμV/m required to ensure an adequate protection ratio at the limit of the service area. It may be noted that measurements on the transmitter aerial, Fig. 6, showed that a discrimination of 30 dB was achieved in the directions of interest. In addition, the calculation has made no allowance for receiving aerial directivity nor polarisation discrimination, although the link will be horizontally polarised whereas the services at both Salcombe and Kewstoke are vertically polarised.

The above analysis considers only one TFM carrier, at the more sensitive offset of 4.4 MHz above the vision carrier. It is necessary to allow for the fact that a second TFM signal will also be transmitted, at an offset of 2.4 MHz. If the interference from each signal was equally visible, an allowance of 3 dB would be necessary. Because the second signal is less damaging, the interfering field strength effectively increases only by about 1 dB. (This argument also applies in the case of co-channel interference to French services).

4.2 Adjacent-channel interference to UK services

The link will operate in Channel 30 which is the upper-adjacent channel to the IBA Channel 4 transmissions from Stockland Hill. The television signals from Stockland Hill are broadcast at an e.r.p. of 250 kW which is 27 dB above the total 500 W

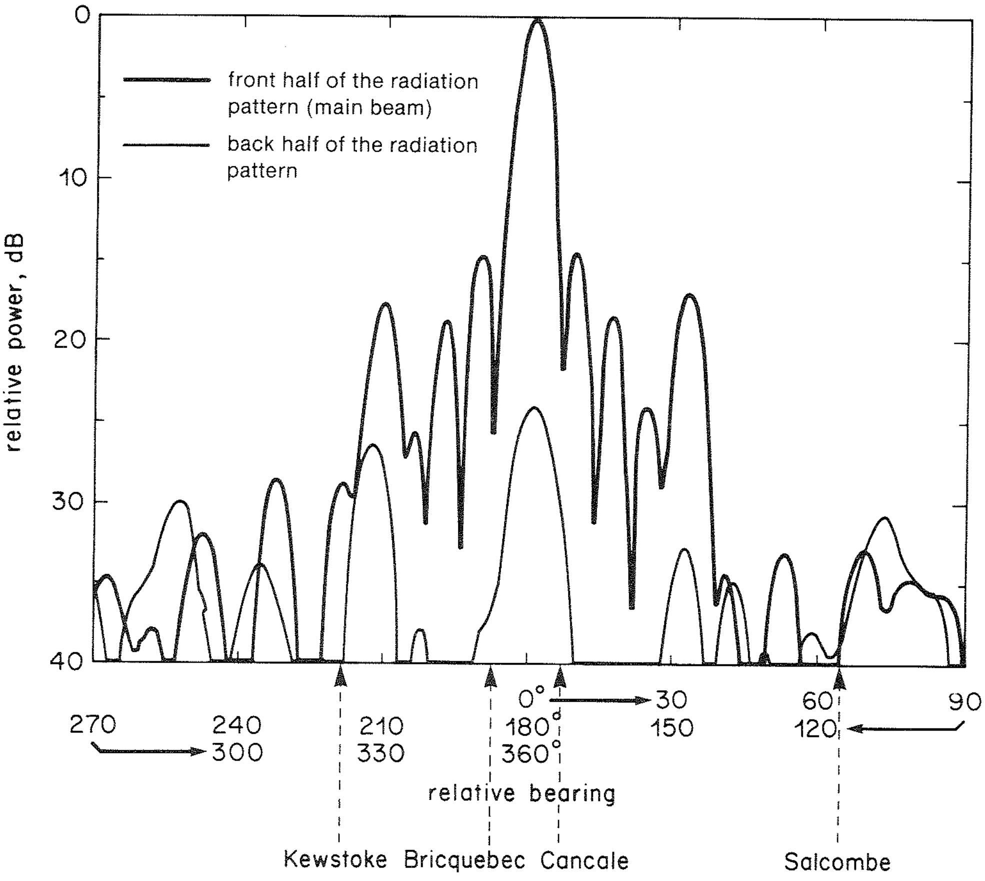

Fig. 6 - Horizontal radiation pattern of the Stockland Hill digital link transmitting aerial.

e.r.p. of the link. Therefore the television signal will be protected by considerably more than the 3 dB protection ratio required for upper-adjacent-channel interference (upper ACI) from one PAL System-I channel into another PAL System-I Channel. The link consists of digitally-modulated carriers, 2.4 MHz and 4.4 MHz above the normal position of vision carrier in the channel, which have been shown[3] to be significantly less damaging than a PAL System-I signal in their interference potential. Therefore, in general, an excellent protection margin exists.

However, a potential problem exists very close to the transmitter in the main beam of the aerial carrying the digitally modulated signal. There is a possibility that the directivity of the existing television transmitting aerial, being greater in the vertical plane than that of the aerial for the link, might give rise to an unsatisfactory upper ACI level for Channel 29 reception in the vicinity of the transmitter.

The vertical radiation pattern of the existing aerial in Channel 29 is shown in Fig 7. The 0 dB reference value represents the maximum e.r.p. of 250 kW. The vertical radiation pattern of the aerial to be used for the link in Channel 30 is shown in Fig. 8, the 0 dB reference represents the maximum e.r.p. of 500 W.

A graph, Fig 9, of e.r.p. versus angle below the horizontal in the direction of Alderney can be drawn. This shows that for angles of less than 20° a carrier-to-interference ratio of better than 12 dB can be expected, which represents an upper ACI protection margin of at least 9 dB. Data for the existing aerial for depression angles greater than 20° is not available, but there are no buildings in the small sector close to the mast bounded by the 20° depression arc and the -12 dB bearings for the horizontal radiation pattern of the link aerial.

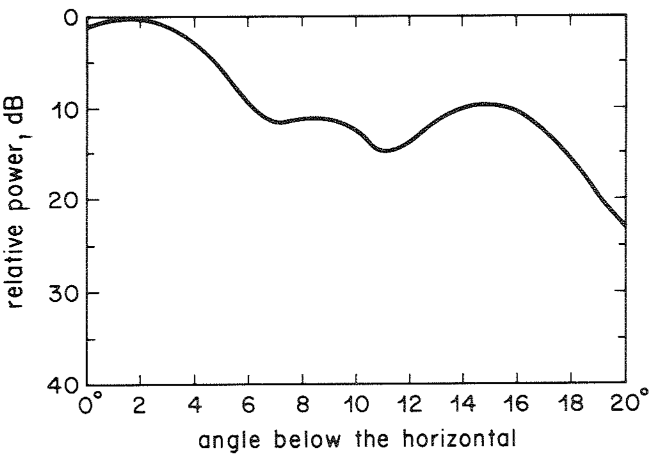

Fig. 7 - Vertical radiation pattern of the Stockland Hill television transmitting aerial in Channel 29.

It can be concluded that there is not a problem with upper ACI as a protection margin of at least 9 dB exists for angles of less than 20° from the horizontal. For angles of greater than 20° from the horizontal there is probably an adequate protection margin but in any case no buildings lie in the main beam of the aerial used for the link.

4.3 Co-channel interference to French services

The part of the French mainland most liable to interference is that near the Cherbourg Peninsula. Two French transmitters in this area broadcast signals on Channel 30; their positions are shown in Fig. 1. The difference in bearing from Stockland Hill between Alderney and Cancale is 8° and between Alderney and Bricquebec is 7°. Cancale is still in the planning stage; Bricquebec is a small station of 1.5 W e.r.p.

The field strength of the digitally modulated signal at the French transmitter sites has been calculated by two methods. The first uses CCIR Recommendation 370[10] and the second is obtained by computer calculation undertaken at BBC Research Department[9]. The calculations involved in the first method are presented in detail in Appendix 2. The computer calculations are based on diffraction over the path terrain profile which is held for the UK and North-West France in a terrain data bank at Research Department. The results obtained by these two methods are summarised in Table 6.

Table 6: Predicted interference from Stockland Hill to French services

Percentage of time	Predicted Field Strength (dBμV/m)			
	Cancale		Bricquebec	
	Rec. 370	Computer prediction	Rec. 370	Computer prediction
50%	-10	-11	-1	-12
10%	13	-	21	-
5%	22	24	25	14
1%	37	33	37	18

These figures assume: an e.r.p. of 250 W at Stockland Hill,
a transmitting aerial height of 439 m a.o.d.,
an omni-directional transmitting aerial, and
a receiving aerial height of 10 m.

The figures obtained from Rec. 370 are for 50% locations. It can be seen from Table 6 that the

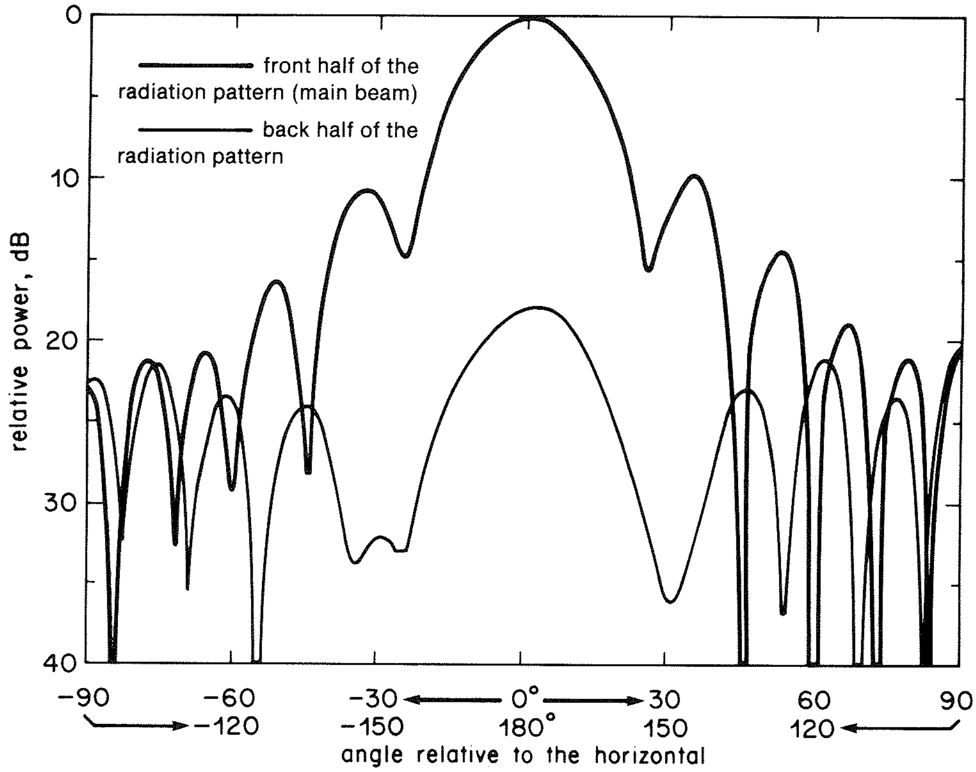

Fig. 8 - Vertical radiation pattern of the Stockland Hill digital link transmitting aerial.

computer calculations generally predict a lower field strength than that predicted by Rec. 370. It is noted in CCIR Report 239[11], a report giving details about the use of Rec. 370, that a single terrain irregularity parameter, Δh, is inadequate to define the attenuation correction factor exactly. As a result Section 6 of the Report suggests that computer methods may be used where greater accuracy is required. Therefore the figures obtained by computer prediction will probably correspond to the measured values most closely. However, for the purposes of calculating interference to French transmissions a worst case figure will be assumed and the figures produced using Rec. 370 will be used.

The protection ratio required by 625-line SECAM System L signals to c.w. interference can be obtained from CCIR Report 655[12]. The protection ratio quoted for tropospheric interference, i.e. interference present for 1% of time, is 39 dB in the case of a carrier frequency 2.4 MHz above the vision carrier and 38 dB in the case of a carrier frequency 4.4 MHz above the vision carrier.

It is noted in Section 3 of Report 655 that when the signal is frequency modulated, a reduction in the necessary protection ratio can be expected. However, no results have been published by the CCIR giving the protection ratio required from digitally modulated signals. Work undertaken at BBC Research Department[3] has shown that a relaxation is permissible and the results are summarised in Table 7.

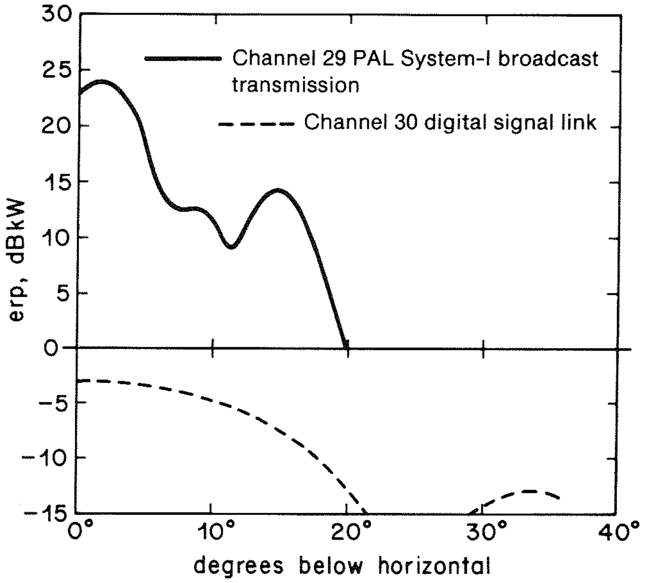

Fig. 9 - Graph of e.r.p. versus angle in a vertical plane from the Stockland Hill transmitter in the direction of Alderney.

Table 7: Relaxation in protection ratio for a digitally modulated carrier for interference to SECAM System L, present for less than 1% time.

Non-controlled frequency offset (MHz)	Min. permissible relaxation (dB)	Resultant protection ratio for digitally modulated carriers (dB)
2.4	7	32
4.4	3	35

The proposed link radiates two signals each at 250 W maximum e.r.p. from a high-gain transmitter aerial. The use of a high gain aerial reduces the e.r.p. in directions away from Alderney whilst maintaining the e.r.p. in the wanted direction and so will reduce the potential area of interference to French transmissions.

The transmitter aerial for the link is composed of four 18-element Yagi aerials mounted to form a 4 by 1 element array in the horizontal direction. The Yagis are spaced two wavelengths apart and the horizontal radiation pattern of the array is shown in Fig. 6. Nulls are positioned on the bearings of the French transmitters at Cancale and Bricquebec. At least 16 dB of protection for French transmissions can be obtained from the transmitting aerial directivity.

The protected field strength for 1% time can now be calculated at the French transmitter sites of Cancale and Bricquebec. They will be valid also for the service areas of the French transmitters as the transmitters are sited on high ground so that the protected field strengths in the service areas will be lower than those calculated at the transmitters themselves.

The protected field strength is given by:

$$E_{pfs(1\%)} = E_{fs(1\%)} + P_{r(1\%)} + T$$

where:

$E_{pfs(1\%)}$ = Protected field strength for 1% time, 50% locations (dBμV/m)

$E_{fs(1\%)}$ = Predicted interfering field strength for 1% time, 50% locations (dBμV/m). Based on Rec. 370 and an e.r.p. of 250 W.

$P_{r(1\%)}$ = Tropospheric Protection Ratio for 625-line SECAM System L to digitally modulated interference. Based on Report 306 and Ref. 3.

T = Transmitting aerial gain in the direction of interest relative to broadside gain.

From the values derived above, the protected field strength can be calculated to be 56 dBμV/m in the directions of Cancale and Bricquebec for a frequency offset of 4.4 MHz and 53 dBμV/m for a frequency offset of 2.4 MHz. In Band IV, the minimum field strength for which protection may be sought in planning a television service[13] is 65 dBμV/m. Therefore it can be concluded that for any given percentage of time the level of interference to French transmissions will be well below the limit recommended by the CCIR. It should be noted that this result is calculated for worst case conditions, and that no allowance has been made for receiving aerial directivity.

In conclusion, using CCIR recommended methods it has been shown that the level of interference to French transmissions is within internationally agreed limits. The worst case of protected field strength for 1% time was calculated to be 56 dBμV/m. This is lower than the 65 dBμV/m level which defines the minimum field strength for which protection may be sought. In addition, it is noted that this is likely to be a worst case calculation for a number of reasons:

a) Computer predictions, which are acknowledged by the CCIR to be more accurate than Rec. 370, predict a lower field strength than was used in the calculation.

b) Calculations were made to the French transmitter sites rather than the service areas, and the former are on high ground.

and c) No allowance has been made for receiving aerial directivity.

5. CONCLUSIONS AND RECOMMENDATIONS

A digital link at UHF has been proposed as a feed for radio programmes to the Channel Islands. The proposed link consists of two, 2.048 Mbit/s data streams each carrying 6 monophonic or 3 stereophonic broadcast channels coded using NICAM-3. Each data stream will be modulated onto a carrier using a Tamed-FM digital modulation method and transmitted in Channel 30, one carrier 2.4 MHz and the other 4.4 MHz above the normal position of vision carrier. The combined signal will be radiated from the UHF station at Stockland Hill at a total e.r.p. of 500 W using a high gain aerial. A log-periodic aerial array on Alderney will be used to receive the signal.

In this Report the planning requirements for such a link have been discussed. It has been shown that, based on the planning figures available, the link will be limited by co-channel interference rather than noise and that a reliability of 99.55% of time should be achieved. However, it is possible that there are other problems which may adversely affect the reliability of the link, e.g. long-delay multipath, about which there is no statistical data. It has been shown that the link is compatible with existing services, both French and UK.

It is recommended that such a link be installed on an experimental basis to determine its actual performance and to test the validity of these theoretical predictions. The levels of the digital signal and co-channel interference from PAL System-I transmissions along with the bit error ratio and other error statistics from the digital demodulator should be measured over a statistically significant time period.

6. ACKNOWLEDGEMENT

The authors would like to acknowledge the work undertaken by P.R. Durrant on the experiment to determine the ruggedness of the digital signal to PAL System-I co-channel interference.

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APPENDIX 1

Equations relating signal power out of an aerial to the field strength of the signal

The signal power obtained from an aerial is related to the field strength of the signal in which the aerial is placed by the following equation:

$$P = \frac{\lambda^2 . G(\theta,\phi) . S^2}{4 . \pi^2 . R}$$

where: $G(\theta,\phi)$ = aerial power gain with respect to a half-wave dipole in the direction of the signal source. The source and aerial are assumed to have the same polarisation.

S = signal field strength, V/m

λ = wavelength, m

R = matched load impedance, Ω

Which can be given in the following form:

$$P(\text{dBm}) = S(\text{dB}\mu\text{V/m}) + G(\text{dBd}) + 20\log\lambda - 10\log R - 105.96 \text{ dB}$$

The matched load impedance for the half-wave dipole reference aerial is 73 Ω, and in this case the wavelength is 0.549 m and the gain of the aerial system is 21.2 dBd. Therefore the expression can be simplified to:

$$P(\text{dBm}) = S(\text{dB}\mu\text{V/m}) - 108.6 \text{ dB}$$

APPENDIX 2

UHF propagation calculation

The predicted field strength has been calculated using Rec. 370[10]. In both cases the calculations are made for 50% locations and a 1 kW e.r.p. This is adjusted later by 6 dB to correspond to the 250 W e.r.p. for each carrier which will be used by the proposed service. Both paths are mixed land/sea paths and so the propagation calculation is done using Method A in Section 5.1 of Report 239[11]. The equations are reproduced as equations (1) and (2) below:

For 50% and 10% time:

$$E_{M,t} = E_{L,t} + \frac{d_S}{d_T} . [E_{S,t} - E_{L,t}] \tag{1}$$

For 5% and 1% time:

$$E_{M,t} = E_{L,t} + A . [E_{S,t} - E_{L,t}] \tag{2}$$

where: $E_{M,t}$ = field strength for mixed path for t % of the time

$E_{L,t}$ = field strength for land path equal in length to the mixed path for t % of the time for $\Delta h = 50$ m

$E_{S,t}$ = field strength for sea path equal in length to the mixed path for t % of the time

d_S = length of sea path

d_T = length of total path

A = interpolation factor given in Fig. 4 of Ref. 11.

There are two French transmitters which are co-channel with the proposed service. These are considered separately.

The data for the path from Stockland Hill to Cancale is as follows:

d_T = 253 km

d_S = 231 km

site height = 229 m a.o.d.

aerial height = 210 m a.g.l.*

height of aerial above mean terrain = 389 m

bearing of Cancale from Stockland Hill = 159° ETN

height of receiving aerial = 10 m a.g.l.

The propagation prediction is shown in Table A2.1.

Table A2.1: Predicted field strength at Cancale

Time %	Interpolation factor A	Field strength (dBμV/m) 50% locations: for 1 kW e.r.p. $E_{L,t}$†			
			$E_{S,t}$‡	$E_{M,t}$	for 250 W e.r.p. $E_{M,t}$
50	-	-6	-4	-4	-10
10	-	1	21	19	13
5	0.84	5	32	28	22
1	0.80	12	51	43	37

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* above ground level.

† No terrain irregularity correction factor is used as the path is almost entirely over sea between 10 km and 50 km from the transmitter and this is allowed for in the sea part of the mixed path.

‡ Field strength over North Sea rather than Mediterranean Sea paths was used as it was thought to be more representative of the English Channel path.

The data for the path from Stockland Hill to Bricquebec is as follows:

$d_T = 182$ km

$d_S = 134$ km

height of aerial above mean terrain = 369 m

bearing of Bricquebec from Stockland Hill = 144° ETN

height of receiving aerial = 10 m a.g.l.

The propagation prediction is shown in Table A2.2.

Table A2.2: Predicted field strength at Bricquebec

Time %	Interpolation factor A	Field strength (dBμV/m) 50% locations: for 1 kW e.r.p. $E_{L,t}$*	$E_{S,t}$†	$E_{M,t}$	for 250 W e.r.p. $E_{M,t}$
50	-	5	7	7	1
10	-	13	34	29	23
5	0.65	16	42	33	27
1	0.60	22	61	45	39

In addition, terrain data indicates that a receiver terrain clearance correction is applicable. This is explained fully in Ref. 11, Section 4.2. In this case an obstruction is present 4 km from the receiver and is 16 m higher than the receiving aerial. This corresponds to an angle of 0.23° and a correction of 2 dB from Fig. 3 of Ref. 11. Thus the predicted field strengths at Bricquebec should be reduced by 2 dB. The results are shown in table A2.3.

Table A2.3: Corrected predicted field strength at Bricquebec

Time %	Field strength (dBμV/m) 50% locations 250 W e.r.p.
50	-1
10	21
5	25
1	37

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* No terrain irregularity correction factor is used as the path is almost entirely over sea between 10 km and 50 km from the transmitter and this is allowed for in the sea part of the mixed path.

† Field strength over North Sea rather than Mediterranean Sea paths was used as it was thought to be more representative of the English Channel path.